Chapter Outline and Learning Objectives

After you have studied this chapter, you should be able to:

**Anatomy of the Heart (p. 223)**
- Describe the anatomy of the heart, and trace the path of blood through it.
- Name the heart valves, and describe their functions.
- Describe the cardiac cycle and the cardiac conduction system.
- Label and explain a normal electrocardiogram.
- Describe how the heartbeat is regulated.
- Describe the conditions that may cause a heart attack.

**Vascular System (p. 234)**
- Name the three types of blood vessels, and describe their structure and function.
- Name the two circuits of the circulatory system, and trace the path of blood from the heart to any organ in the body and back to the heart.
- Describe the functions of the fetal circulatory structures.

**Features of the Circulatory System (p. 244)**
- Define pulse.
- Describe the factors that control blood pressure and blood flow in the arteries, capillaries, and veins.
- Define hypertension, and distinguish between systolic pressure and diastolic pressure.

**Effects of Aging (p. 246)**
- Anatomical and physiological changes occur in the circulatory system as we age.

**Working Together (p. 246)**
- The circulatory system works with other systems of the body to maintain homeostasis.

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Medical Focus
Congestive Heart Failure (p. 227)
The Electrocardiogram (p. 230)

MedAlert
Preventing Heart Attacks (p. 232)

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The heart is enclosed by a pericardium whose layers have been wholly or partially dissected away.
The circulatory system consists of the heart and the blood vessels. The heart pumps the blood, and the blood vessels, which comprise the vascular system, conduct the blood toward and away from the heart. The primary function of the circulatory system is keeping the blood moving in its circular path. The other functions of the circulatory system are the same as those noted for blood in chapter 11.

**Anatomy of the Heart**

The heart is a cone-shaped, muscular organ about the size of a clenched fist. It is located in the thorax between the lungs, anterior to the backbone and posterior to the sternum. Its apex is tilted to the left, and about two-thirds of the heart is located to the left of the body’s midline.

**Pericardial Membranes**

The heart lies within a sac formed by the pericardial membranes (fig. 12.1). First is the fibrous pericardium, a layer of fibrous connective tissue that adheres to the blood vessels at the heart’s base and the sternal wall of the thorax and the diaphragm below. Next comes the parietal pericardium, a serous membrane that is separated by a small space, called the pericardial cavity, from the epicardium (visceral pericardium), another serous membrane. These serous membranes produce a liquid called the pericardial fluid, which lubricates them and reduces friction as the heart beats.

The epicardium is a part of the heart wall that also has two other layers. The myocardium is the thickest part of the heart wall and is made up of cardiac muscle (see fig. 4.13). When cardiac muscle fibers contract, the heart beats. The inner endocardium includes an endothelium formed from simple squamous epithelium that not only lines the heart but also continues into and lines the blood vessels. The endothelium’s smooth nature helps prevent blood from clotting unnecessarily.

**Chambers of the Heart**

The heart has four chambers: The right and left atria (sing. atrium) are superior to the right and left ventricles (fig. 12.2). The atria are smaller and have thinner walls than the ventricles. Internally, the atria are separated by the interatrial septum, and the ventricles are separated by the interventricular septum (fig. 12.3). Thus, the heart has a right and left side.
Right Atrium

Three large openings are located in the wall of the right atrium. The superior vena cava enters superiorly, and the inferior vena cava enters inferiorly on the posterior side (see fig. 12.3). There is also an opening between the right atrium and the right ventricle that is guarded by a valve appropriately called an atrioventricular (AV) valve. This valve, like other heart valves, directs the flow of blood and prevents any backflow. This particular AV valve is also known as the tricuspid valve because it has three cusps or flaps (fig. 12.4b).

Although not shown in figure 12.3, another opening into the right atrium is the coronary sinus, a vein that carries oxygen-poor blood from the heart wall. The coronary sinus opens into the right atrium between the inferior vena cava and the tricuspid valve.

Right Ventricle

The wall of the right ventricle contains conical extensions of myocardium called papillary muscles. Fibrous cords from the papillary muscles, called the chordae tendineae, attach to the cusps of the tricuspid valve. The chordae tendineae support the valve and prevent the cusps from inverting (turning back into the right atrium) when the right ventricle fills with blood and begins to contract.

The pulmonary trunk leaves the right ventricle. This opening has a semilunar valve with cusps that resemble half-moons. This valve, called the pulmonary semilunar valve, prevents blood from flowing back into the right ventricle (see fig. 12.4).
Chapter 12 The Circulatory System

**Left Atrium**

The *left atrium* is smaller than the right atrium but has thicker walls. Four pulmonary veins, two from each lung, enter the left atrium. The openings do not have valves. An atrioventricular valve between the left atrium and the left ventricle is called the *bicuspid* or mitral valve because it has two cusps.

**Left Ventricle**

The cavity of the *left ventricle* is oval-shaped, while that of the right ventricle is crescent-shaped. It appears to be smaller in size because the walls are thicker.

The papillary muscles in the left ventricle are quite large, and the chordae tendineae are thicker and stronger than those in the right ventricle. These chordae tendineae and papillary muscles keep the bicuspid valve from inverting into the left atrium when the left ventricle contracts.

The opening by which the aorta leaves the left ventricle is closed by a semilunar valve called the *aortic semilunar valve* (see fig. 12.4). The semilunar cusps of this valve are larger and thicker than those of the pulmonary semilunar valve. Openings just beyond the aortic semilunar valve lead to the coronary arteries, blood vessels that lie on and nourish the heart itself (see fig. 12.2). The heart valves are listed in table 12.1.

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**The heart has a right and left side and four chambers, consisting of two atria and two ventricles. The heart valves are the tricuspid valve, the pulmonary semilunar valve, the bicuspid valve, and the aortic semilunar valve.**
Valves of the Heart

<table>
<thead>
<tr>
<th>Valve</th>
<th>Location</th>
<th>Function</th>
<th>Valve</th>
<th>Location</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tricuspid valve</td>
<td>Right atrioventricular valve</td>
<td>Prevents blood from moving from right ventricle into right atrium during ventricular contraction</td>
<td>Bicuspid valve</td>
<td>Left atrioventricular valve</td>
<td>Prevents blood from moving from left ventricle into left atrium</td>
</tr>
<tr>
<td>Pulmonary semilunar valve</td>
<td>Entrance to pulmonary trunk</td>
<td>Prevents blood from moving from pulmonary trunk into right ventricle during ventricular relaxation</td>
<td>Aortic semilunar valve</td>
<td>Entrance to aorta</td>
<td>Prevents blood from moving from aorta into left ventricle</td>
</tr>
</tbody>
</table>

Double Pump

The heart is a double pump. The right side of the heart sends oxygen-poor blood, which is also high in carbon dioxide, to the lungs, and the left side sends oxygen-rich blood throughout the body. Therefore, the blood actually travels in two circuits: (1) from the heart to the lungs and back to the heart, and (2) from the heart to the body and back to the heart. The right side of the heart is a pump for the first circuit, and the left side is a pump for the second. The left ventricle has the harder job of pumping blood to all parts of the body; therefore, its walls are thicker than those of the right ventricle.

Path of Blood in the Heart

The path of blood through the heart is traced as follows: Blood enters the right atrium from the superior and inferior vena cavae (ve’ne ca’ve), the largest veins in the body. Contraction of the right atrium forces the blood through the tricuspid valve to the right ventricle. The right ventricle pumps the blood through the pulmonary semilunar valve, which allows blood to enter the pulmonary trunk. The pulmonary trunk divides into the pulmonary arteries, which take blood to the lungs.

From the lungs, blood enters the left atrium from the pulmonary veins. Contraction of the left atrium forces blood through the bicuspid valve into the left ventricle. The left ventricle then pumps the blood through the aortic semilunar valve into the aorta (a-or’tah), the largest artery in the body. The aorta sends blood to all body tissues. Notice that oxygen-poor blood never mixes with oxygen-rich blood and that blood must pass through the lungs before entering the left side of the heart.

Heartbeat

Blood is forced out of the ventricles with each heartbeat. The stroke volume is the volume of blood pumped by a ventricle with each beat. The cardiac output is the volume of blood pumped by one ventricle per minute. In a resting adult, the cardiac output is usually about 5 liters—approximately the amount of blood in the body. The Medical Focus reading on this page describes congestive heart failure, a condition that occurs when the cardiac output is insufficient to meet the body’s needs.

Congestive Heart Failure

Congestive heart failure occurs when the cardiac output is insufficient to meet the body’s needs. The term congestive is used because heart failure is accompanied by increased venous volume and pressure. When the left side of the heart fails to pump blood, due perhaps to a heart attack or valve failure, fluid backs up in the lungs and produces pulmonary congestion and edema. The result is shortness of breath and fatigue; if severe, pulmonary edema can be fatal. During the past 20 years, deaths from congestive heart failure have increased by one-third, even though heart attacks are down 25% and strokes are down 40%.

Treatment consists of the three Ds: diuretics (which increase urinary output), digoxin (which increases the heart’s contractile force), and dilators (which relax the blood vessels). Surgical repair and replacement are also possible. Heart transplants are done, or a piece of muscle is taken from the back, brought into the thorax, and wrapped around the heart.
Cardiac Cycle

From the description of the path of blood through the heart, it might seem that the right and left side of the heart beat independently of one another, but actually, they contract together. First, the two atria contract simultaneously; then, the two ventricles contract at the same time. The word systole (sis’to-le) refers to contraction of heart muscle, and the word diastole (di-as’to-le) refers to relaxation of heart muscle; therefore, atrial systole is followed by ventricular systole. The word systole is used alone, it usually refers to the left ventricular systole.

If the heart contracts, or beats, about 70 times a minute, then each heartbeat lasts about 0.85 second. Each heartbeat, or cardiac cycle (fig. 12.5), consists of the following elements:

<table>
<thead>
<tr>
<th>Time</th>
<th>Atria</th>
<th>Ventricles</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. 0.15 sec.</td>
<td>Systole</td>
<td>Diastole</td>
</tr>
<tr>
<td>2. 0.30 sec.</td>
<td>Diastole</td>
<td>Systole</td>
</tr>
<tr>
<td>3. 0.40 sec.</td>
<td>Diastole</td>
<td>Diastole</td>
</tr>
</tbody>
</table>

This shows that, while the atria contract, the ventricles relax, and vice versa, and that all chambers rest at the same time for 0.40 second. The short systole of the atria is appropriate since the atria send blood only into the ventricles. The muscular ventricles require a longer systole because they pump blood throughout the whole body. When the word systole is used alone, it usually refers to the left ventricular systole.

The heartbeat is divided into three phases: (1) the atria contract during atrial systole, (2) the ventricles contract during ventricular systole, and (3) both the atria and ventricles relax during diastole.
**Heart Sounds**

A heartbeat produces the familiar “lub-dub” sounds. The sounds are due to vibrations caused by pressure changes that occur when the chambers contract and the valves close. The “lub” sound is heard when the ventricles contract and the atrioventricular valves close. This sound lasts longer and has a lower pitch than the “dub” sound, which is heard when the semilunar valves close and the ventricles relax. Heart murmurs, or a slight slush sound after the “lub,” are often due to ineffective valves that allow blood to pass back into the atria after the atrioventricular valves have closed.

Rheumatic fever resulting from a streptococcal infection is one cause of a faulty valve, particularly the mitral valve. **Mitral stenosis** is a narrowing of the opening of the bicuspid valve. If operative procedures are unable to open and/or restructure the valve, it may be replaced by an artificial valve.

**Cardiac Conduction System**

The heart contains specialized cardiac muscle fibers with both muscular and nervous characteristics: They can conduct cardiac impulses throughout the myocardium. These fibers are a part of the cardiac conduction system.

The heartbeat is intrinsic, meaning that the heart will beat independently of outside nervous stimulation. This ability is due to a specialized mass of cardiac fibers called the sinoatrial (SA) node. The SA node is located in the posterior wall of the right atrium, just below the opening for the superior vena cava (fig. 12.6). The SA node is known as the pacemaker because it initiates the heartbeat and automatically sends out an excitation impulse every 0.85 second. The atria then contract, and the impulse is sent on to a second node, called the atrioventricular (AV) node. This node is located in the wall of the right atrium near the septum just superior to the ventricles. The AV node conducts the impulse to a group of large fibers called the atrioventricular (AV) bundle (bundle of His). The AV bundle, which is in the upper part of the interventricular septum, divides into right and left bundle branches. These branches give rise to Purkinje fibers (pur-kin’je), which cause the ventricles to contract. Contraction begins at the apex and moves toward the base, where the blood vessels are located.

With the contraction of any muscle, including the myocardium, electrolyte changes occur that can be detected by electrical recording devices. A record of the changes that occur during a cardiac cycle is called an
The Electrocardiogram

A graph that records the electrical activity of the myocardium during a cardiac cycle is called an electrocardiogram or ECG. The change in polarity as the heart’s chambers contract and then relax is measured in millivolts by electrodes placed on the skin and wired to a voltmeter (instrument that measures voltage).

An ECG consists of a set of waves: the P wave, a QRS complex, and a T wave (fig. 12A). The P wave represents depolarization of the atria as an impulse started by the SA node travels throughout the atria. The P wave signals that the atria are going to be in systole and that the atrial myocardium is about to contract. The QRS complex represents depolarization of the ventricles following excitation of the Purkinje fibers. It signals that the ventricles are going to be in systole and that the ventricular myocardium is about to contract. The QRS complex shows greater voltage changes because the ventricles have more muscle mass than the atria. The T wave represents repolarization of the ventricles. It signals that the ventricles are going to be in diastole and that the ventricular myocardium is about to relax. Atrial diastole does not show up on an ECG because the voltage changes are masked by the QRS complex.

An ECG records the length of the heartbeat and therefore can be used to detect a rate that is slower or faster than normal. Fewer than 60 heartbeats per minute is called bradycardia, and more than 100 heartbeats per minute is called tachycardia.

An ECG also detects abnormal heartbeats. The term arrhythmia describes a heartbeat displaying an abnormal rhythm. The heart is in fibrillation when it beats rapidly, but the contractions are uncoordinated. Fibrillation is common when a person is having a heart attack. The heart can sometimes be defibrillated by briefly applying a strong electrical current to the chest.

The conduction system of the heart includes the SA node, the AV node, the AV bundle, the bundle branches, and the Purkinje fibers. The SA node causes the atria to contract. The AV node and the rest of the conduction system cause the ventricles to contract.

Regulation of the Heartbeat

While, as discussed in the preceding section, the heartbeat is intrinsic, the rate is regulated by the nervous system. A cardiac control center in the medulla oblongata of the brain can alter the heartbeat rate by way of the autonomic nervous system (fig. 12.7). Parasympathetic motor impulses conducted by the vagus nerve cause the heartbeat to...
slow down, and sympathetic motor impulses conducted by sympathetic motor fibers cause the heartbeat to increase.

The cardiac control center receives sensory input from receptors within the circulatory system. For example, pressoreceptors (baroreceptors) are present in the aorta just after it leaves the heart and in the carotid arteries, which take blood from the aorta to the brain. If blood pressure falls, as it might if we stand up quickly, the pressoreceptors signal the cardiac control center. Thereafter, sympathetic motor impulses to the heart cause the heartbeat rate to increase. Once blood pressure begins to rise above normal, nerve impulses from the cardiac control center cause the heartbeat rate to decrease. Such reflexes also help control cardiac output and, therefore, blood pressure, as discussed later.

The cardiac control center is under the influence of the cerebrum and the hypothalamus. Therefore, when we feel anxious, the sympathetic motor nerves are activated, and the adrenal medulla releases the hormones norepinephrine and epinephrine. The end result is an increase in heartbeat rate. On the other hand, activities such as yoga and meditation lead to activation of the vagus nerve, which slows the heartbeat rate.

Other factors also influence the heartbeat rate. A cold temperature slows the heartbeat rate, which is why the body temperatures of a person undergoing open-heart surgery is lowered. The correct plasma concentration of electrolytes, such as potassium ($K^+$) and calcium ($Ca^{2+}$), is important to a regular heartbeat.

The heartbeat rate is regulated largely by the autonomic nervous system.
Cardiac Disorders

Cardiac disorders are especially associated with atherosclerosis (ath"er-o"skle-ro'sis), an accumulation of soft masses of fatty materials, particularly cholesterol, beneath the inner linings of the arteries. Such deposits are called plaque (plak), and as they develop, they tend to protrude into the vessel and interfere with blood flow. As discussed in the MedAlert reading on this page, diet can be used to control blood cholesterol level, and therefore plaque, when necessary.

If the coronary artery (see fig. 12.2) is partially occluded (blocked) by the presence of atherosclerosis, the individual may suffer from ischemic (is-kem’ik) heart disease. Although enough oxygen may normally reach the heart, the individual experiences insufficiency during exercise or stress. At that time, the individual may suffer angina pectoris (an-ji’nah pek’to-ris), chest pain that is often accompanied by a radiating pain in the left arm.

Sometimes blood clots in an unbroken blood vessel particularly if plaque is present. A thrombus is a stationary blood clot in an unbroken blood vessel, and an embolus is a blood clot that is moving along in the bloodstream. Thromboembolism is present when a blood clot breaks away from its place of origin and is carried to a new

MedAlert

Preventing Heart Attacks

The coronary arteries are small blood vessels that serve the needs of the heart. When coronary arteries become occluded to any degree, coronary heart disease (CHD) is present. Although CHD develops slowly over a period of years, a heart attack (myocardial infarction) can develop quite suddenly. Most heart attacks occur when a blood clot forms in a coronary artery already narrowed by plaque (fig. 12B). Then the portion of the heart deprived of oxygen and nutrients dies, and surrounding tissue may also be damaged.

The following factors increase the risk of CHD:

- Male gender or postmenopausal female
- Family history of heart attack under age 55
- Tobacco usage (for example, smoking cigarettes, chewing tobacco)
- Severe obesity (30% or more overweight)
- Hypertension (high blood pressure)
- Unfavorable blood levels of HDL and LDL cholesterol
- Impaired circulation to the brain or the legs
- Diabetes mellitus

Hypertension (high blood pressure) is a major factor in the development of cardiovascular disease, and two controllable behaviors contribute to it: smoking cigarettes (including filtered cigarettes) and obesity. While cigarette smoking is a habit to avoid, most of its detrimental side effects can be reversed when the individual stops smoking. Since obese individuals find it very difficult to lose weight, weight control should be a lifelong endeavor.

Investigators have identified several behaviors that may help to reduce the possibility of heart attack and stroke. Exercise is critical. Sedentary individuals have a risk of cardiovascular disease that is about double that of those who are very active. One physician recommends that his patients walk for one hour, three times a week. Stress reduction is also desirable for heart attack and stroke prevention. Daily meditation and yogalike stretching and breathing exercises may help reduce stress.

A diet low in saturated fats and cholesterol retards plaque development and thereby helps reduce the chance of heart attack. Cholesterol is carried in the blood by two types of plasma proteins:

1. LDL (low-density, or “bad,” lipoprotein) transports cholesterol to the tissues from the liver.
2. HDL (high-density, or “good,” lipoprotein) transports cholesterol out of the tissues to the liver.

A diet low in saturated fat and cholesterol will probably lower the total blood cholesterol level and perhaps the LDL level of some individuals, but most likely will not raise the HDL level. Certain drugs apparently can raise the HDL level, and exercise is also sometimes effective.
location. Thromboembolism leads to heart attacks when the embolus blocks a coronary artery and a portion of the heart dies due to lack of oxygen. Dead tissue is called an infarct, and therefore, the individual who has had a heart attack has had a **myocardial infarction** (mi’o-kar’dé-al in-fark’shun).

Some of the cardiovascular risk factors, such as male gender and family history, are inherent in an individual. Other risk factors, however, can be controlled if the individual believes it is worth the effort. The four great admonitions for a healthy life—eating a low-fat, low-cholesterol diet; getting regular exercise; maintaining proper weight; and refraining from smoking—all contribute to keeping the blood cholesterol level low and the blood pressure within a normal range.

Two surgical procedures are associated with **occluded coronary arteries**. In **thrombolytic therapy**, a plastic tube is threaded into an artery of an arm or leg and is guided through a major blood vessel toward the heart. Once the tube reaches a blockage, a balloon attached to the end of the tube can be inflated to break up the clot, a procedure called **balloon angioplasty**. In some cases, a small metal-mesh cylinder called a vascular stent is inserted into a blood vessel during balloon angioplasty. The stent functions to hold the vessel open and decreases the risk of future occlusion. Alternately, streptokinase may be injected to dissolve the clot. In a **coronary bypass operation**, a portion of a blood vessel from another part of the body, such as a large vein in the leg, is sutured from the aorta to the coronary artery, past the point of obstruction. This procedure allows blood to flow normally again from the aorta to the heart.

Questions
1. In what ways does a low-fat, low-cholesterol diet help prevent CHD?
2. Describe what happens during a myocardial infarction.
Vascular System

Blood Vessels

The blood vessels comprise the vascular system. Blood vessels are of three types: arteries, capillaries, and veins (fig. 12.8).

Arteries and Arterioles

Arteries (fig. 12.8a) transport blood away from the heart. They have thick walls composed of an inner endothelium layer (tunica intima), an outer connective tissue layer (tunica externa), and also a thick middle layer (tunica media) of elastic fibers and smooth muscle. The elastic fibers enable an artery to expand and accommodate the sudden increase in blood volume that results after each heartbeat. Arterial walls are sometimes so thick that they are supplied with blood vessels.

Arterioles are small arteries just visible to the naked eye. The middle layer of these vessels has some elastic tissue but is composed mostly of smooth muscle whose fibers encircle the arteriole. Contraction of smooth muscle cells is under involuntary control by the autonomic nervous system. If the muscle fibers contract, the lumen (cavity) of the arteriole decreases; if the fibers relax, the lumen of the arteriole enlarges. Whether arterioles are constricted or dilated affects blood pressure. The greater the number of vessels dilated, the lower the resistance to blood flow, and hence, the lower the blood pressure, and vice versa.
Arteriosclerosis  The plaques associated with atherosclerosis may also restrict nutrition of the smooth muscle tissue and elastic fibers comprising the artery wall, causing these tissues to deteriorate and lesions to form. This is accompanied by the deposition of calcium salts and the formation of nonelastic scar tissue, resulting in increased rigidity of the vessel wall. This process of hardening of the arteries, or arteriosclerosis, not only contributes to hypertension but also increases the risk of a heart attack or stroke.

A stroke, also called a cerebrovascular accident (CVA), occurs when a portion of the brain is deprived of oxygen. Two reasons for strokes are hypertension, which can cause a cerebral artery to burst, or a blood clot, which can prevent blood flow to the brain.

**Capillaries**

Arterioles branch into capillaries (fig. 12.8b), which are extremely narrow, microscopic blood vessels with a wall composed of only one layer of endothelial cells. Capillary beds (a network of many capillaries) are present in all regions of the body; consequently, a cut in any body tissue draws blood. Capillaries are an important part of the circulatory system because nutrient and waste molecules are exchanged only across their thin walls. Oxygen and glucose diffuse out of capillaries into the tissue fluid that surrounds cells, and carbon dioxide and other wastes diffuse into the capillaries (see fig. 11.6). Since capillaries serve the needs of the cells, the heart and other vessels of the circulatory system can be considered a means by which blood is conducted to and from the capillaries.

Not all capillary beds (fig. 12.9) are open or in use at the same time. For instance, after a meal, the capillary beds of the digestive tract are usually open, and during muscular exercise, the capillary beds of the skeletal muscles are open.

Most capillary beds have a shunt that allows blood to move directly from arteriole to a venule (a small vessel leading to a vein) when the capillary bed is closed. Sphincter muscles, called precapillary sphincters, encircle the entrance to each capillary. When the capillary bed is closed, the capillary sphincters are constricted, preventing blood from entering the capillaries; when the capillary bed is open, the capillary sphincters are relaxed. As would be expected, the larger the number of capillary beds open, the lower the blood pressure.
Veins and Venules

Veins and smaller vessels called venules carry blood from the capillary beds to the heart. First, the venules drain the blood from the capillaries and then join together to form a vein. The wall of a vein is much thinner than that of an artery because the middle layer of muscle and elastic fibers is thinner (see fig. 12.8c). Within some veins, especially in the major veins of the arms and legs, valves allow blood to flow only toward the heart when they are open and prevent the backward flow of blood when they are closed.

At any given time, more than half of the total blood volume is found in the veins and venules. If blood is lost due to, for example, hemorrhaging, sympathetic nervous stimulation causes the veins to constrict, providing more blood to the rest of the body. In this way, the veins act as a blood reservoir.

Arteries and arterioles carry blood away from the heart, veins and venules carry blood to the heart, and capillaries join arterioles to venules.

Varicose Veins and Phlebitis

Varicose veins are abnormal and irregular dilations in superficial (near the surface) veins, particularly those in the lower legs. Varicose veins in the rectum, however, are commonly called piles, or more properly, hemorrhoids. Varicose veins develop when the valves of the veins become weak and ineffective due to backward pressure of the blood. The problem can be aggravated when venous blood flow is obstructed by crossing the legs or by sitting in a chair so that its edge presses against the back of the knees.

Phlebitis (flē-bi’tus), or inflammation of a vein, is a more serious condition, particularly when a deep vein is involved. When blood in a large, unbroken vein clots, thromboembolism can occur. In this instance the embolus, which is a blood clot moving along in the bloodstream, may eventually come to rest in a pulmonary arteriole, blocking circulation through the lungs. This condition, termed pulmonary embolism, can result in death.

Path of Circulation

The vascular system, which is diagrammatically represented in figure 12.10, can be divided into two circuits: the pulmonary circulation, which circulates blood through the lungs, and the systemic circulation, which serves the needs of the body’s tissues.

Pulmonary Circulation

The path of blood through the lungs can be traced as follows: Blood from all regions of the body first collects in the right atrium and then passes into the right ventricle, which pumps it into the pulmonary trunk. The pulmonary trunk divides into the pulmonary arteries, which divide into the arterioles of the lungs. The arterioles then take blood to the pulmonary capillaries, where carbon dioxide and oxygen are exchanged. The blood then enters the pulmonary venules and flows through the pulmonary veins back to the left atrium. Since the blood in the pulmonary arteries is oxygen-poor but the blood in the pulmonary veins is oxygen-rich, it is not correct to say that all arteries carry blood that is high in oxygen and that all veins carry blood that is low in oxygen. In fact, it is just the reverse in the pulmonary system.

The pulmonary arteries transport oxygen-poor blood to the lungs, and the pulmonary veins return oxygen-rich blood to the heart.

Systemic Circulation

The systemic circulation includes all of the other arteries and veins of the body. The largest artery in the systemic circuit is the aorta, and the largest veins are the superior and inferior venae cavae. The superior vena cava collects blood from the head, chest, and arms, and the inferior vena cava collects blood from the lower body regions. Both venae cavae enter the right atrium. The aorta and venae cavae are the major pathways for blood in the systemic system.

The path of systemic blood to any organ in the body begins in the left ventricle, which pumps blood into the aorta. Branches from the aorta go to the major body regions and organs. Tracing the path of blood to any organ in the body requires only mentioning the aorta, the proper branch of the aorta, the organ, and the returning vein to the vena cava. In many instances, the artery and vein that serve the same organ have the same name. For example, the path of blood to the kidneys is: left ventricle; aorta; renal artery; arterioles, capillaries, venules; renal vein; inferior vena cava; right atrium. In the systemic circuit, unlike the pulmonary system, arteries contain oxygen-rich blood and appear bright red, while veins contain oxygen-poor blood and appear purplish.

The systemic circulation transports blood from the left ventricle of the heart to the arteries, arterioles, and capillaries, and then from the capillaries to the venules and veins to the right atrium of the heart. It serves the body proper.
figure 12.10 Blood vessels in the pulmonary and systemic circulations. Except for the pulmonary system, the veins (blue-colored) carry oxygen-poor blood, and the arteries (red-colored) carry oxygen-rich blood. Arrows indicate the direction of blood flow. Lymph vessels collect excess tissue fluid and return it to the subclavian veins in the shoulders.
The Major Systemic Arteries

By examining the path of the aorta (fig. 12.11) after it leaves the heart, one can see why it is divided into the ascending aorta, the aortic arch, and the descending aorta. The coronary arteries, which supply blood to the heart, branch off of the ascending aorta.

Three major arteries branch off the aortic arch: the brachiocephalic artery, the left common carotid artery, and the left subclavian artery. The brachiocephalic artery divides into the right common carotid and the right subclavian arteries. These blood vessels serve the head (right and left common carotids) and arms (right and left subclavians).

The descending aorta is divided into the thoracic aorta, which branches off to the organs within the thoracic cavity, and the abdominal aorta, which branches off to the organs in the abdominal cavity. The major branches of the aorta are listed in table 12.2, and most of them are shown in figure 12.11.

The descending aorta ends when it divides into the common iliac arteries that branch into the internal iliac artery and the external iliac artery. The internal iliac artery serves the pelvic organs, and the external iliac artery serves the legs.

The Major Systemic Veins

Figure 12.12 shows the major veins of the body. The external and internal jugular veins drain blood from the brain, head, and neck. The external jugular veins enter the subclavian veins that, along with the internal jugular veins, enter the brachiocephalic veins. These vessels merge, giving rise to the superior vena cava.

In the abdominal cavity, as discussed in more detail later, the hepatic portal vein receives blood from the abdominal viscera and enters the liver. Emerging from the liver, the hepatic veins enter the inferior vena cava.

In the pelvic region, veins from the various organs enter the internal iliac veins, while the veins from the legs enter the external iliac veins. The internal and external iliac veins become the common iliac veins that merge, forming the inferior vena cava. Table 12.3 lists the principal veins that enter the venae cavae.

All the arteries in the systemic circulation can be traced from the aorta. All the veins in the systemic circulation can be traced to the venae cavae.
superficial temporal v.

anterior facial v.

internal jugular v.

brachiocephalic v.

axillary v.

cephalic v.

brachial v.

basilic v.

median cubital v.

renal v.

radial v.

right gonadal v.

ulnar v.

common iliac v.

external iliac v.

femoral v.

popliteal v.

peroneal v.

posterior tibial v.

small saphenous v.

anterior tibial v.

external jugular v.

subclavian v.

superior vena cava

azygos v.

hepatic v.

inferior vena cava

ascending lumbar v.

left gonadal v.

internal iliac v.

great saphenous v.
Vital Systemic Circulatory Routes

Blood Supply to the Brain  The brain is supplied with oxygenated blood in arteries (vertebral and internal carotids) that give off branches. These branches join to form the circle of Willis, a circle in the region of the pituitary gland (fig. 12.13). The value of having the blood vessels join in this way is that, if one becomes blocked, the brain still can receive blood via three other routes.

Circulation to the brain includes the circle of Willis, which protects the brain from reduced blood supply.

Blood Supply to the Heart  The coronary arteries (see fig. 12.2), which are a part of the systemic circulation, are extremely important because they serve the myocardium. (The heart is not nourished by the blood in its chambers.) The right and left coronary arteries arise from the aorta, just beyond the aortic semilunar valve. They lie on the exterior surface of the heart, where they branch off in various directions into smaller arteries and arterioles. The coronary capillary beds join to form venules, which converge into the cardiac veins. The cardiac veins follow the path of the coronary arteries and finally empty into the coronary sinus, an enlarged vein on the posterior surface of the heart. The coronary sinus enters the right atrium. Although the coronary arteries receive blood under high pressure, they have a very small diameter and can become occluded, or blocked, as discussed in the MedAlert reading “Preventing Heart Attacks” on page 232.

Circulation to the myocardium is dependent upon the proper functioning of the coronary arteries.
Blood Supply to the Liver  The hepatic portal system (fig. 12.14) carries blood from the stomach, intestines, and other organs to the liver. A portal system is one that begins and ends in capillaries; thus, there are two sets of capillaries between an artery and a final vein. The superior mesenteric artery brings blood to the small intestine, where the first set of capillaries occurs. Various veins join to form the hepatic portal vein, which takes blood to the liver, where the second set of capillaries occurs. Then, the hepatic veins leave the liver to enter the inferior vena cava.

Fetal Circulation

As figure 12.15 shows, the fetus has four circulatory features that are not present in adult circulation:

1. Foramen ovale, or oval window, an opening between the two atria. This window is covered by a flap of tissue that acts as a valve.
2. Ductus arteriosus, or arterial duct, a connection between the pulmonary artery and the aorta.
3. Umbilical arteries and vein, vessels that travel to and from the placenta, leaving waste and receiving nutrients.
4. Ductus venosus, or venous duct, a connection between the umbilical vein and the inferior vena cava.

All of these features can be related to the fact that the fetus does not use its lungs for gas exchange, since it receives oxygen and nutrients from the mother’s blood at the placenta.

The path of blood in the fetus can be traced, beginning from the right atrium (fig. 12.15). Most of the blood that enters the right atrium passes directly into the left atrium by way of the foramen ovale because the blood pressure in the right atrium is somewhat greater than that in the left atrium. The rest of the fetal blood entering the right atrium passes into the right ventricle and out through the pulmonary trunk, but because of the ductus arteriosus, most blood then passes into the aorta. Notice that by whatever route blood takes, most of it reaches the aorta instead of the lungs.

Blood within the aorta travels to the various branches, including the iliac arteries, which connect to the umbilical arteries leading to the placenta. Exchange between maternal and fetal blood takes place at the placenta. Blood in the umbilical arteries is oxygen-poor, but blood in the umbilical vein, which travels from the placenta, is oxygen-rich. The umbilical vein enters the ductus venosus, which passes directly through the liver. The ductus venosus then joins with the inferior vena cava, a vessel that contains oxygen-poor blood. The vena cava returns this mixture to the right atrium.
The most common of all cardiac defects in the newborn is the persistence of the foramen ovale. With the tying of the umbilical cord and the expansion of the lungs, blood enters the lungs in quantity. Return of this blood to the left side of the heart usually causes a small valve located on the left side of the interatrial septum to close the foramen ovale. Incomplete closure occurs in nearly one out of four individuals, but even so, blood rarely passes from the right atrium to the left atrium because either the opening is small or it closes when the atria contract. In a small number of cases, the passage of oxygen-poor blood from the right side to the left side of the heart is sufficient to cause cyanosis, a bluish cast to the skin. This condition can now be corrected by open-heart surgery.

The ductus arteriosus closes because endothelial cells divide and block the duct. Remains of the arterial duct and parts of the umbilical arteries and vein are later transformed into connective tissue.

Fetal circulation includes four unique features: (1) the foramen ovale, (2) the ductus arteriosus, (3) the umbilical arteries and vein, and (4) the ductus venosus. These features are necessary because the fetus does not use its lungs for gas exchange.
Features of the Circulatory System

When the left ventricle contracts, blood is sent out into the aorta under pressure.

Pulse

The surge of blood entering the arteries causes their elastic walls to swell, but then they almost immediately recoil. This alternate expanding and recoiling of an arterial wall can be felt as a pulse in any artery that runs close to the surface. The pulse is often checked by placing several fingers on the radial artery, which lies near the outer border of the palm side of the wrist near the thumb. The pulse can also be obtained at other locations (fig. 12.16). The pulse rate indicates the heartbeat rate and also gives information about the strength and rhythm of the heartbeat.

Blood Pressure

Blood pressure is the force of blood against a blood vessel wall. Two aspects of blood pressure are considered: (1) how blood pressure is maintained in the arteries and arterioles, and (2) how blood pressure varies in other parts of the circulatory system.

Maintaining Blood Pressure

The two factors that affect blood pressure are cardiac output (p. 227) and peripheral resistance. The following factors can cause cardiac output and peripheral resistance to rise:

- **Cardiac output**
  - Heart rate increase
  - Blood volume increase

- **Peripheral resistance**
  - Arterial constriction

The pressoreceptors mentioned earlier (see fig. 12.7) regulate the heartbeat rate and also blood pressure. For example, when a person stands up quickly and blood pressure falls, the pressoreceptors signal a cardiac control center and a vasomotor control center in the medulla oblongata. Impulses conducted along sympathetic nerve fibers then cause heartbeat rate to increase and the arterioles to constrict to a greater degree. The end result is a rise in blood pressure.

Certain hormones also cause blood pressure to rise. Epinephrine and norepinephrine increase the heart rate, as mentioned in chapter 10. The renin-angiotensin-aldosterone mechanism (also discussed in chapter 10) constricts arterioles and leads to an increase in blood volume when sodium and water are reabsorbed. ADH (antidiuretic hormone) released by the posterior pituitary also causes a rise in blood volume and therefore blood pressure (see fig. 10.11).

What factors lead to a reduction in blood pressure? If blood pressure rises above normal, the pressoreceptors signal the cardiac control center and vasomotor control center in the medulla oblongata. Subsequently, the heart rate decreases and the arterioles dilate. In addition, recall that atrial natriuretic factor opposes the actions of aldosterone and ADH by decreasing blood pressure (see fig. 10.11). Therefore, blood pressure is under the control of both the nervous system and the endocrine system.

Blood pressure is dependent on cardiac output and peripheral resistance. These are regulated by the activation of autonomic nerve impulses and by the release of certain hormones.
**Blood Flow in Arteries, Arterioles, and Capillaries**

Blood pressure accounts for the movement of blood in the arteries and arterioles. Blood pressure decreases with distance from the left ventricle of the heart. Blood pressure is higher in the arteries than in the arterioles, and there is a sharp drop in pressure when blood reaches the capillaries (fig. 12.17). This decrease in pressure may be correlated with the increase in the total cross-sectional area of the vessels; there are more arterioles than arteries, and many more capillaries than arterioles. Also, blood moves much slower in the capillaries than it does in the aorta, to allow time for the exchange of molecules between the blood and the tissues.

**Blood Flow in Veins and Venules**

Movement of blood in the veins is not due to blood pressure, but to skeletal muscle contraction. When skeletal muscles contract, they press against the weak walls of the veins, causing the blood to move past a valve (see fig. 12.8c). Once past the valve, blood is prevented from flowing backward. Blood flow gradually increases in the venous system, due to a progressive reduction in the cross-sectional area, as small venules join to form veins. Because blood pressure in the veins is low, the return of venous blood to the heart depends on several adaptations. As already mentioned, the squeezing action produced by skeletal muscle contraction and the presence of one-way valves move blood in veins. These adaptations, along with pressure differences between the thoracic and abdominal cavities, help return venous blood to the heart. As noted in chapter 14, when a person inhales, the diaphragm contracts, creating a partial vacuum in the thoracic cavity. Because pressure is higher in the abdominal cavity, the pressure difference causes blood to move from the abdominal to the thoracic veins.

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**figure 12.17** Blood pressure changes throughout the systemic circulation. Blood pressure decreases with distance from the left ventricle.
Hypertension

Blood pressure is usually measured in the brachial artery with a sphygmomanometer, an instrument that records changes in terms of millimeters of mercury. Normal resting blood pressure for a young adult is 120/80. The higher number is the systolic pressure, the pressure recorded in an artery when the left ventricle contracts, and the lower number is the diastolic pressure, the pressure recorded in an artery when the left ventricle relaxes. About 20% of all Americans are estimated to have hypertension (hi’per-ten’shun), or high blood pressure. Reasons for the development of hypertension are varied, as discussed in the MedAlert reading on page 232. One possible reason is associated with the kidney’s secretion of renin (chapter 10). The renin-angiotensin-aldosterone system leads to absorption of sodium and high blood pressure. The same effect can be brought about directly by excess salt in the diet.

Blood pressure is a measure of the systolic and diastolic pressures. Hypertension is elevated blood pressure.

Effects of Aging

The heart generally grows larger with age, primarily because of fat deposition in the epicardium and myocardium. In many middle-aged people, the heart is covered by a layer of fat, and the number of collagenous fibers in the endocardium increases. With age, the valves, particularly the aortic semilunar valve, become thicker and more rigid.

As a person ages, the myocardium loses some of its contractile power and some of its ability to relax. The resting heart rate decreases throughout life, and the maximum possible rate during exercise also decreases. With age, the contractions become less forceful; the heart loses about 1% of its reserve pumping capacity each year after age 30.

In the elderly, arterial walls tend to thicken with plaque and become inelastic, signaling that atherosclerosis and arteriosclerosis are present. The chances of coronary thrombosis and heart attack increase with age. Increased blood pressure was once believed to be inevitable with age, but now hypertension is known to be the result of other conditions, such as kidney disease and atherosclerosis. The MedAlert reading for this chapter describes how diet and exercise in particular can help prevent atherosclerosis.

The occurrence of varicose veins increases with age, particularly in people who are required to stand for long periods. Thromboembolism as a result of varicose veins can lead to death if a blood clot settles in a major branch of a pulmonary artery. (This disorder is called pulmonary embolism.)

Working Together

The accompanying illustration shows how the circulatory system works with other organ systems of the body to maintain homeostasis. All the organ systems of the body are interrelated.

BodyWorks CD-ROM  
The module accompanying chapter 12 is Cardiovascular System.
working together

Circulatory System

Integumentary System
Blood vessels deliver nutrients and oxygen to skin, carry away wastes; blood clots if skin is broken. Skin prevents water loss; helps regulate body temperature; protects blood vessels.

Skeletal System
Blood vessels deliver nutrients and oxygen to bones; carry away wastes. Rib cage protects heart; red bone marrow produces blood cells; bones store Ca^{2+} for blood clotting.

Muscular System
Blood vessels deliver nutrients and oxygen to muscles; carry away wastes. Muscle contraction keeps blood moving in heart and blood vessels.

Nervous System
Blood vessels deliver nutrients and oxygen to neurons; carry away wastes. Brain controls nerves that regulate the heart and dilation of blood vessels.

Endocrine System
Blood vessels transport hormones from glands; blood services glands; heart produces atrial natriuretic hormone. Epinephrine increases blood pressure; ADH, aldosterone, and atrial natriuretic hormone factors help regulate blood volume; growth factors control blood cell formation.

Lymphatic System/Immunity
Blood vessels transport leukocytes and antibodies; blood services lymphoid organs and is source of tissue fluid that becomes lymph. Lymphoid organs produce and store formed elements; lymph vessels transport leukocytes and return tissue fluid to blood vessels; spleen serves as blood reservoir; filters blood.

Respiratory System
Blood vessels transport gases to and from lungs; blood services respiratory organs. Gas exchange in lungs rid body of carbon dioxide, helping to regulate the pH of blood; breathing aids venous return.

Digestive System
Blood vessels transport nutrients from digestive tract to body; blood services digestive organs. Digestive tract provides nutrients for plasma protein formation and blood cell formation; liver detoxifies blood, makes plasma proteins, destroys old red blood cells.

Urinary System
Blood vessels deliver wastes to be excreted; blood pressure aids kidney function; blood services urinary organs. Kidneys filter blood and excrete wastes; maintain blood volume, pressure, and pH; produce renin and erythropoietin.

Reproductive System
Blood vessels transport sex hormones; vasodilation causes genitalia to become erect; blood services reproductive organs. Sex hormones influence cardiovascular health; sexual activities stimulate cardiovascular system.
### Basic Key Terms

- **aorta** (a-or’tah), p. 227
- **arteriole** (ar-te’re-ol), p. 234
- **artery** (ar’ter-e), p. 234
- **atrioventricular (AV) node** (a”tre-o-ven-trik’u-lar nōd), p. 229
- **atrioventricular valve** (a”tre-o-ven-trik’u-lar valv), p. 224
- **atrium** (a’tre-um), p. 223
- **bicuspid valve** (bi-kus’pid valv), p. 225
- **capillary** (kap’I-lär”e), p. 235
- **circle of Willis** (ser’kl ov wil’is), p. 241
- **coronary artery** (kor’O-na-re ar’ter-e), p. 241
- **diastole** (di-as’to-le), p. 228
- **endocardium** (en”do-kar’de-um), p. 223
- **heart** (hart), p. 223
- **heart valve** (valv), p. 224
- **hepatic portal system** (hē-pat’ik por’tal sis’tem), p. 242
- **inferior vena cava** (in-fēr’e-or ve’nah ka’vah), p. 227
- **interatrial septum** (in”ter-a’tre-al sep’tum), p. 223
- **interventricular septum** (in”ter-ven-trik’u-ler sep’-tum), p. 223
- **myocardium** (mi”o-kar’de-um), p. 223
- **pacemaker** (pās’māk-er), p. 229
- **pericardial membrane** (per”i-kar’dé-al mem’brān), p. 223
- **pulmonary circulation** (pul’mo-ner”e ser“ku-lā’shun), p. 236
- **pulse** (puls), p. 244
- **Purkinje fiber** (pur-kin’je fi’ber), p. 229
- **semilunar valve** (sem”e-lu’nar valv), p. 224
- **sinoatrial (SA) node** (si”no-a’tre-al nōd), p. 229
- **superior vena cava** (su-pēr’e-ur ve’nah ka’vah), p. 227
- **systemic circulation** (sis-tem’ik ser“ku-la’shun), p. 236
- **systole** (sis’to-le), p. 228
- **tricuspid valve** (tri-kus’pid valv), p. 224
- **vein** (ven’ān), p. 236
- **ventricle** (ven’tri-kl), p. 223
- **venule** (ven’ ŭl), p. 236

### Clinical Key Terms

- **angina pectoris** (an-ji’nah pek’to-ris), p. 232
- **arrhythmia** (ah-rith’me-ah), p. 230
- **arteriosclerosis** (ar-te”re-o-sklē-ro’sis), p. 235
- **atherosclerosis** (ath”er-o”sklē-ro’sis), p. 232
- **bradycardia** (brâ’dē’kar’de-ah), p. 230
- **cerebrovascular accident (CVA)**, (ser”e-bro-vas’ku-lar ak’si-dent), p. 235
- **congestive heart failure** (kon-je’s’tiv hart fâl’yer), p. 227
- **coronary bypass operation** (kor’o-na-re bi’pas op-er-a’shun), p. 233
- **cyanosis** (si”ah-no’sis), p. 243
- **electrocardiogram** (e-lek”tro-kar’dē-o-gram”), p. 230
- **fibrillation** (fi”bri-la’shun), p. 230
- **heart transplant** (hart tranz’plant), p. 227
- **hemorrhoid** (hem’roid), p. 236
- **hypertension** (hi”per-ten’shun), p. 246
- **ischemic heart disease** (is-kem’ik hart dî-zē’z’), p. 232
- **mitral stenosis** (mi’tral sten-o’sis), p. 229
- **myocardial infarction** (mi”o-kar’dé-al in-fark’shun), p. 233
- **occluded coronary arteries** (ō-klood’ed kor’ō-na-re ar’ter-ēz), p. 233
- **phlebitis** (fi”li-bi’tus), p. 236
- **plaque** (plak), p. 232
- **pulmonary embolism** (pul’mo-ner”e em’bo-lizm), p. 236
- **tachycardia** (ta”kē-kar’de-ah), p. 230
- **thromboembolism** (throm”bo-em’bol-lizm), p. 232
- **thrombolytic therapy** (throm”bo-li’tik ther’ah-pe), p. 233
- **varicose vein** (var’i-kos vân), p. 236
Summary

I. Anatomy of the Heart
A. The heart has a right and left side and four chambers, consisting of two atria and two ventricles. The heart valves are the tricuspid valve, the pulmonary semilunar valve, the bicuspid valve, and the aortic semilunar valve.
B. The right side of the heart pumps blood to the lungs, and the left side pumps blood to the tissues.
C. The heartbeat is divided into three phases: (1) the atria contract, (2) the ventricles contract, and (3) both the atria and ventricles rest. To put it another way: When the atria are in systole, the ventricles are in diastole, and vice versa; finally, all chambers are in diastole.
D. The heart sounds are due to the closing of the heart valves.
E. The conduction system of the heart includes the SA node, the AV node, the AV bundle, the bundle branches, and the Purkinje fibers. The SA node causes the atria to contract. The AV node and the rest of the conductive system cause the ventricles to contract.
F. The heartbeat rate is regulated largely by the autonomic nervous system.
G. Myocardial infarction is often preceded by atherosclerosis, angina pectoris, and thromboembolism.

II. Vascular System
A. Arteries and arterioles carry blood away from the heart, veins and venules carry blood to the heart, and capillaries join arterioles to venules.
B. The pulmonary arteries transport oxygen-poor blood to the lungs, and the pulmonary veins return oxygen-rich blood to the heart.
C. The systemic circulation transports blood from the left ventricle of the heart to the arteries, arterioles, and capillaries, and then from the capillaries to the venules and veins to the right atrium of the heart. It serves the body properly.
D. All the arteries in the systemic circulation can eventually be traced from the aorta.
E. All the veins in the systemic circulation can be traced to the vena cavae.
F. Circulation to the brain includes the circle of Willis, which protects the brain from reduced blood supply.
G. Circulation to the heart is dependent upon the proper functioning of the coronary arteries.
H. The hepatic portal system carries blood from the stomach and intestines to the liver.
I. Fetal circulation includes four unique features: (1) the foramen ovale, (2) the ductus arteriosus, (3) the umbilical arteries and vein, and (4) the ductus venosus. These features are necessary because the fetus does not use its lungs for gas exchanges.

III. Features of the Circulatory System
A. The pulse rate indicates the heartbeat rate.
B. Blood pressure is dependent on cardiac output and peripheral resistance. These are regulated by the activation of autonomic nerve impulses and by the release of certain hormones.
C. Blood pressure steadily decreases with distance from the heart’s left ventricle. Blood pressure causes the flow of blood in the arteries and arterioles. Skeletal muscle contraction causes the flow of blood in the venules and veins, and valves prevent backflow of blood.
D. Blood pressure is a measure of the systolic and diastolic pressures. Hypertension is elevated blood pressure.

Study Questions

1. Describe the structure of the heart, including its chambers and valves. (pp. 223–25)
2. Trace the path of blood in the pulmonary circuit, as it travels from and returns to the heart. (p. 227)
3. Describe the cardiac cycle (using the terms systole and diastole), and explain the heart sounds. (pp. 228–29)
4. Describe the circulatory disorders that can lead to a heart attack. (pp. 232–33)
5. What types of blood vessels are in the body? Discuss their structure and function. (pp. 234–36)
6. Trace the path of blood from the mesenteric arteries to the aorta, indicating which of the vessels are in the pulmonary circulation. (pp. 236–38)
7. What is blood pressure, and what does 120/80 mean? (pp. 244, 245)
8. In which type of vessel is blood pressure highest? In which type of vessel is it lowest? In which type of vessel is blood velocity lowest and why? Why is this beneficial? What factors assist venous return of the blood? (p. 245)
Objective Questions

Fill in the blanks.

1. When the left ventricle contracts, blood enters the ________.
2. The right side of the heart pumps blood to the ________.
3. The ________ node is known as the pacemaker.
4. Arteries are blood vessels that take blood ________ the heart.
5. The blood vessels that serve the heart are the ________ arteries and veins.
6. The major blood vessels taking blood to the arms are the ________ arteries and veins. Those taking blood to the legs are the ________ arteries and veins.
7. Blood vessels to the brain end in a circular path known as the ________.
8. The human body contains a hepatic portal system that takes blood from the ________ to the ________.
9. The force of blood against the walls of a vessel is termed ________.
10. Blood moves in arteries due to ________ and in veins due to ________.
11. The blood pressure recorded when the left ventricle contracts is called the ________ pressure, and the pressure recorded when the left ventricle relaxes is called the ________ pressure.
12. The two factors that affect blood pressure are ________ and ________.
13. In the fetus, the opening between the two atria is called the ________, and the connection between the pulmonary artery and the aorta is called the ________.
14. The valve between the left atrium and left ventricle is the ________ or mitral valve.

Medical Terminology Reinforcement Exercise

Consult Appendix B for help in pronouncing and analyzing the meaning of the terms that follow.

1. cryocardioplegia (kri-o-kar”de-o-ple’je-ah)
2. echocardiography (ek”o-kar”de-og’rah-fe)
3. percutaneous transluminal coronary angioplasty (per”ku-ta’ne-us trans”loo’mi-nal kor’ö-na-re an’je-o-plas”te)
4. vasoconstriction (vas”o-kon-strik’shun)
5. valvuloplasty (val’vu-lo-plas”te)
6. arteriosclerosis (ar-te”re-o-sklé-ro’sis)
7. tachycardia (tak”e-kar’dé-ah)
8. antihypertensive (an”ti-hi’per-tensiv)
9. arrhythmia (ah-rith”me-ah)
10. thromboendarterectomy (throm”bo-end”ar-ter-ek’to-me)

Website Link

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